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Central and Arctic Region

Canadian Science Advisory Secretariat
Science Advisory Report 2016/037

STATUS OF BELUGA (*Delphinapterus leucas*) IN CUMBERLAND SOUND, NUNAVUT

*Beluga (*Delphinapterus leucas*) by G. Kuehl.*

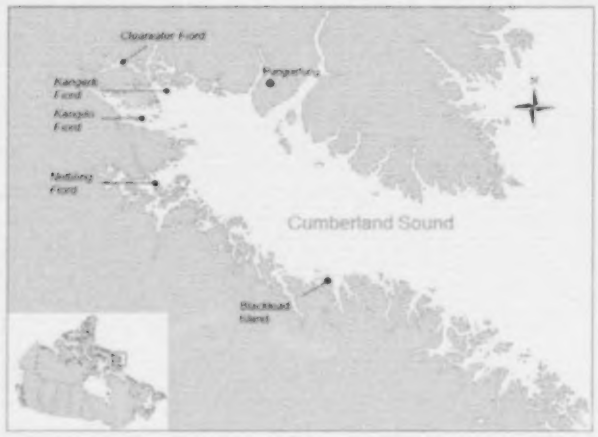

Figure 1. Map of study area.

Context:

Inuit traditional knowledge and scientific studies have shown that most belugas in Cumberland Sound remain in Cumberland Sound year round (Figure 1). Genetic evidence is still insufficient to determine if this potential population is distinct from other Arctic beluga populations. Therefore, Cumberland Sound belugas continue to be managed as a distinct stock. Since 1998, Fisheries and Oceans Canada (DFO) and the Pangnirtung Hunters and Trappers Organization (HTO) have conducted research to update the abundance estimate of Cumberland Sound belugas. This stock of belugas is designated as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and a Recovery Potential Assessment (RPA) was completed in 2005. Population modeling using abundance estimates from surveys flown in 1990 and 1999, produced a pre-commercial whaling estimate of 8,500 animals, and an abundance estimate of 2,000 animals (rounded to the nearest 100) in 2002 (DFO 2005). Subsequent discussions with stakeholders identified a recovery objective of 5,000 animals to be achieved by the end of the century.

Aerial surveys were conducted in August 2005, but it was not possible to obtain an estimate of abundance due to poor weather. Surveys flown in August 2009 produced an estimate of 800 belugas corrected for diving animals. A new survey was flown in August 2014.

Fisheries management has requested that Science develop a population model that incorporates the 2014 and previous aerial survey results, and if appropriate, provide advice on an updated population abundance estimate and recommend sustainable harvest levels that is adjusted to account for hunting losses.

September 2016

Canada

SUMMARY

- Cumberland Sound belugas (CSB) are managed as a distinct stock and are thought to remain within Cumberland Sound throughout the year. They are designated as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).
- CSB are harvested by hunters from the hamlet of Pangnirtung. Since 2002, the quota for the community has been 41 whales.
- An aerial survey was flown in August 2014 to estimate the abundance of CSB. After correcting for animals that were diving and therefore not visible to the survey aircraft, the survey produced an abundance estimate of 1,200 belugas (Standard Error (SE) = 200, rounded to the nearest 100 animals).
- A population model that incorporates reported harvest information, was fitted to abundance estimates from the Cumberland Sound beluga stock using Bayesian methods to obtain an estimate of current abundance and population trend. Multiple model runs using different combinations of survey data from 1980–2014 and harvest data from 1960–2015 were completed. All runs yielded similar estimates with a current stock estimate of around 1,000 animals and indicate that the stock may be declining. These estimates are lower than those predicted by the previous assessments on which the current quota was based.
- The preferred model used the harvest data from 1960–2015 and fitted to four aerial surveys flown between 1990 and 2014. The estimated current stock abundance from this run is 1,000 (95% Credibility Intervals: 500–2,000, rounded to the nearest 100) belugas.
- The current management objective is for the stock to recover to 5,000 animals by 2091. This would require reaching an interim management objective of 1,235 animals by 2025.
- If CSB is to recover to the identified management objective, then harvest reductions are required. However, based upon the model used, the probability of the stock increasing to the interim target level within 10 years is very low, even under conditions where no harvesting occurs. The estimated probability of the stock recovering to the interim target level is estimated to be 10%, 21%, 26% and 32% for a Total Allowable Landed Catch (TALC) of 25, 10, 5 and 0 whales, respectively.
- Harvest advice was also generated using the Potential Biological Removal (PBR) method. Based upon the model estimate of current abundance, and using a recovery factor of 0.5, the estimated PBR is eight belugas. The PBR estimate includes all sources of human mortality, such as landings, struck and lost, non-reporting, and bycatch.
- The TALC estimated using the PBR method is the PBR minus other sources of mortality not included in reported catch (e.g., struck and lost, non-reported harvest and other human related mortality). If levels of other sources of mortality are assumed to be 42% of the actual harvest, then the TALC would be five belugas.
- Correlation among some model parameters was identified. This is not likely to affect model estimates, but suggests that our estimates of uncertainty may be conservative. A longer time series of survey estimates, improved survey correction factors and improved harvest reporting (including struck and lost estimates) are required to reduce uncertainty associated with estimating CSB abundance and trend.

BACKGROUND

Commercial harvesting of CSB began in the mid-1800s and continued until 1920, as commercial whalers supplemented their catches of bowhead whales, with skins and oil from CSB (Figure 2). After 1920, various trading companies continued to organise drive fisheries of CSB for oil and skins until about 1966 (Stewart 2004 unpublished report). Since the 1970s, this stock has been the subject of several research studies that concluded the stock was severely depleted and could not sustain a large take. In the early 1980s, beluga numbers were estimated to be in the low hundreds and a quota system was established to regulate the subsistence harvest. Since 1990, five sets of surveys have been conducted to monitor the status of the CSB stock. Aerial surveys done in 2005 were unsuccessful due to photographic problems and extreme weather. However, four sets of surveys were successfully completed in 1990, 1999, 2009 and 2014. This document reports on the results of the 2014 aerial survey, which was undertaken to update the abundance estimate of the Cumberland Sound beluga stock and determine if adjustments to the current quota for Cumberland Sound belugas are needed.

Species Biology

Belugas have a circumpolar distribution. They are medium-sized toothed whales with adult growing to 3 to 5 m, depending on the population, and reaching weights up to 1,900 kg. Belugas lack a dorsal fin, which is believed to be an adaptation to inhabiting ice-covered waters. Mating is thought to occur during winter or early spring. Calves are born after a 14 month gestation and lactation lasts roughly 18 months. Beluga calves spend 2–3 years with their mother, during which time, they perform several seasonal migrations. It has been suggested that this extended parent-offspring association could provide the opportunity for learning migration routes. The calving interval is three years. At birth, the calves are brown or dark bluish in colour. The skin becomes lighter in colour as they mature, gradually turning to grey and then to white. Sexual maturity might fall between 8 and 14 years of age, and longevity may be 60+ years.

Across their entire range, belugas are known to visit estuaries and river mouths during summer, which has led to the view that they are a shallow water species. However, satellite telemetry and aerial survey data have shown that beluga can undertake regular trips to and from estuaries, sometimes hundreds of kilometres away, over the course of the summer.

ASSESSMENT

The Harvest

Data are available from the commercial (1868–1966) and subsistence (1956–2015) harvests, but there are significant gaps in the data, thus these statistics represent minimum estimates only (Figure 2). In addition, there has been irregular harvest reporting of beluga harvests over the last decade. This assessment used only reported catches from 1960 to 2015.

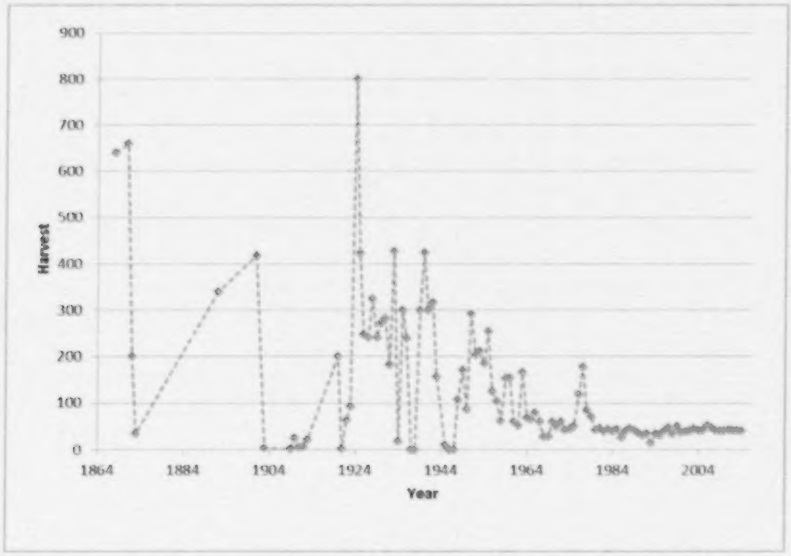

Figure 2. Reported harvests of Cumberland Sound belugas from 1864–2014. Catch data are missing for several years after 2003. For these years it was assumed that the entire TALC was taken.

Abundance and impact of harvest levels

Surveys to estimate CSB abundance have been flown since the early 1980s, but those conducted prior to 1990 are thought to be negatively biased to an unknown degree because survey coverage of areas outside of Clearwater Fiord was irregular and largely coastal (Table 1). In 2014, a complete photographic survey was performed in Clearwater Fiord and line transect visual survey was completed in areas outside of Clearwater Fiord (Figure 3).

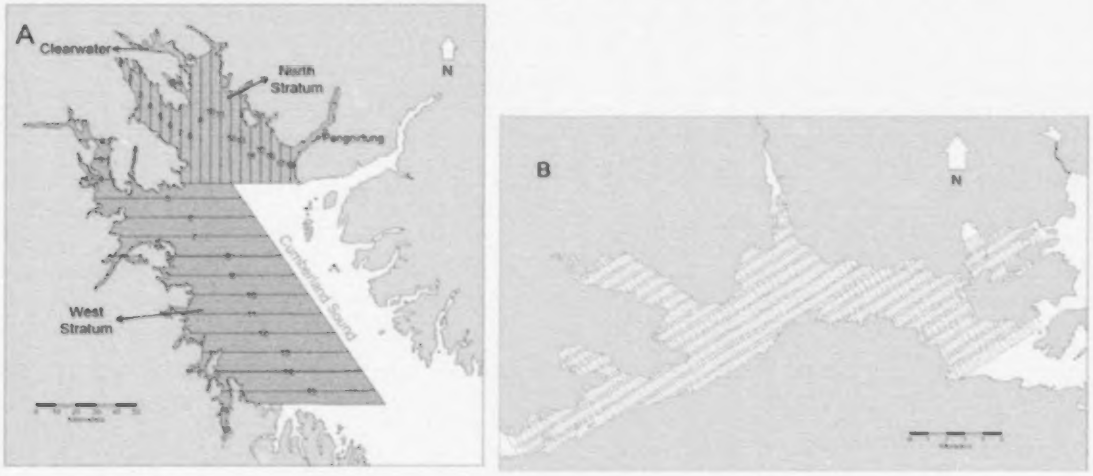

Figure 3. A) Map of 2014 aerial survey showing the three strata and the transect lines for the visual survey. B) Map of the 2014 photographic surveys of Clearwater Fiord showing the footprint of individual photographs.

Table 1. Estimates of Cumberland Sound beluga abundance within Clearwater Fiord (the area of main concentration), outside Clearwater Fiord, and the two areas combined (Marcoux and Hammill 2016).The percentage of belugas that were outside of Clearwater Fiord (% outside) and the coefficient of variation (CV) of the survey estimates are also presented. Note that no CVs were calculated for the surveys conducted prior to 1990. Complete photographic coverage refers only to Clearwater Fiord.

Year	Clearwater Fiord	Outside Clearwater Fiord	Total CV%	CV	% outside Clearwater Fiord	Survey method	Survey coverage
1980	178	637	815		78	non-systematic aerial visual and photographic	Clearwater, Kangilo Fiords
1981	919	50	969		5	non-systematic aerial visual	Clearwater, Kangilo Fiords, west coast of Cumberland Sound
1982	1054	177	982		18	non-systematic aerial visual and photographic	Clearwater, Kangerk, Kangilo Fiords, northern part of Nettiling Fiord, west coast of Cumberland Sound
1985	1775	0	1775		0	systematic photo and visual	Clearwater Fiord, West stratum
1986	1102	5	1107		0	systematic and non-systematic visual and photographic	Clearwater Fiord, North stratum
1990	1180	0	1180	0.10	0	complete photographic and visual systematic	Clearwater Fiord, North stratum
1999	1924	347	2270	0.09	15	complete photographic, visual systematic	Clearwater Fiord, North and West strata
2009	303	546	849	0.38	64	complete photographic, visual systematic	Clearwater Fiord, North and West strata
2014	603	548	1151	0.21	48	complete photographic, visual systematic	Clearwater Fiord, North and West strata

Since whales spend much of their time below the surface and hence are not visible to be counted, aerial survey estimates of whales at the surface must be adjusted to account for diving whales. Satellite transmitters were deployed on belugas in Clearwater Fiord and the amount of time that animals were visible from the surface was estimated. An adjustment factor was applied to the counts of animals at the surface that was obtained from the photographic count and the estimates from the visual surveys. The adjustment factor varied with water turbidity from a low of 2.06 to a high of 4.46.

After adjusting for animals that were below the surface, the estimated abundance of CSB resulting from the aerial survey in 2014 was 603 animals in Clearwater Fiord and 548 animals outside of the Fiord for a total of 1,200 (95% Confidence Interval (CI): 800–1700, rounded to the nearest 100) belugas (Marcoux et al. 2016).

A population model that was based on our understanding of the dynamics of beluga populations and available 1960–2015 catch history information was fitted to the time-series of abundance estimates obtained from the aerial surveys (Table 1, Figure 2).

The impact of harvesting was examined in three ways. First, the draft *Species at Risk Act* (SARA) Recovery Plan for CSB identified the management objective of allowing the stock to increase to 5,000 animals by 2091 (DFO Unpublished report). If the current stock size is approximately 1,000 belugas, then to reach this recovery target in 75 years would require an average annual rate of increase of approximately 2.1% (Figure 5). We suggest that, rather than projecting into the future 75 years, interim targets be identified to more easily evaluate progress towards the recovery objective. If we assume an average annual rate of increase of approximately 2.1%, then after 10 years the stock should increase to about 1,235 animals. Thus, in a first analysis, we examined the probability of the stock reaching 1,235 belugas assuming different Total Allowable Landed Catch (TALC) levels over a 10-year period.

In a second analysis, the sustainable yield was estimated. The sustainable yield was defined as the annual TALC, over a ten-year period, which would maintain a constant population. We used different catch levels and expressed the impacts of these as the probability of a population decline.

In a third analysis, we estimated Potential Biological Removal (PBR) levels. We assumed a Recovery Factor (F_R) of 0.5 which has been used by DFO for species designated by COSEWIC as Threatened.

The PBR threshold is calculated as:

$$PBR = N_{min} \cdot 0.5 \cdot R_{max} \cdot F_R$$

Where R_{max} is the maximum rate of population increase. The default value for cetaceans is 0.04,

F_R is a recovery factor (between 0.1 and 1), and

N_{min} is the value of the 20-percentile of the log-normal distribution of the estimated population size (Wade 1998).

PBR is the overall acceptable level of removals attributed to human causes e.g., subsistence harvest, animals killed but not recovered, and other human related mortality. Therefore, to obtain an estimate of the TALC, the PRB value must be adjusted to account for losses.

Model Results

The model was fitted to aerial survey estimates of abundance to provide estimates of CSB abundance and trends for the years 1960–2015. The abundance estimates are quite variable between surveys. This is believed to be a consequence of surveying a small population of animals that tend to be very aggregated. Belugas are very social animals and behaviour within aggregations is probably highly correlated, which could increase the uncertainty associated with the survey estimates. For model parameters struck and lost, carrying capacity, and the starting population, there was little change between the input values and the model estimates of these parameters. There was also some correlation between some parameters (struck and lost, carrying capacity and the starting population size). These problems have little impact on the median estimates of population size, but tend to underestimate the uncertainty associated with the model estimates i.e., the model gives the impression that it gives a better fit to the data than is the case. The underestimation of uncertainty likely results from too few data being used to inform the model. Nonetheless, because the model uses more information with respect to our understanding of beluga population dynamics, the harvest data, and fits to several survey estimates, these estimates of CSB abundance are considered to be more reliable than those obtained from a single survey.

Some differences were observed between model runs for estimates of population size in 1960, but all model runs provided a similar view of a declining stock that has decreased to around 1,000 belugas in 2015 (Table 2).

Table 2. Model estimates of current stock size (median), coefficient of variation (CV), 95% Credibility intervals, minimum population size used in the PBR calculation (N_{min}) and PBR from the different runs used to fit the model.

Survey data included	2015 Estimate	SE	CV	95% Credibility Interval	N_{min}	PBR
1980–2014	1,000	310	0.31	500–1,700	704	7
1980–2014 + 25%*	1,000	310	0.31	500–1,800	788	8
1985–2014	1,000	340	0.34	500–1,800	774	8
1990–2014	1,100	450	0.41	500–2,200	763	8
1990–2014†	1,000	390	0.39	500–2,000	765	8

*In this model, pre-1990 survey estimates were increased by 25% to account for whales outside of Clearwater Fiord.

† In this model, the shaping parameter (θ) that describes how density-dependent relationship affects growth and recovery was fixed to 1. This is the preferred model.

The preferred model was the formulation that fitted only to the 1990–2014 aerial survey data, with a fixed shaping parameter ($\theta = 1$) that describes how density-dependent relationship affects growth and recovery. The estimated starting population (rounded to the nearest 100) in 1960 was estimated to be 3,400 animals, while the current (2015) population estimate is 1,000 animals (rounded to the nearest 100; Figure 4).

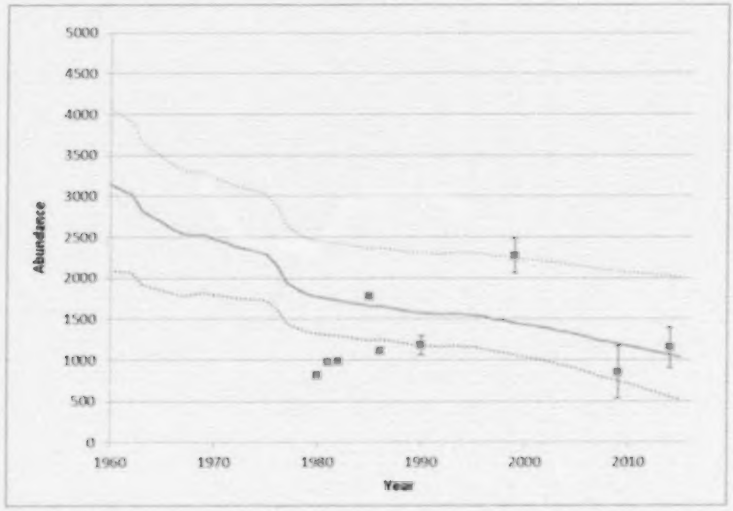

Figure 4. Model estimates of Cumberland Sound beluga abundance from preferred model fitted to estimates from aerial surveys flown in 1990, 1999, 2009 and 2014 (red squares with ± 95% Confidence Limits). These survey estimates are corrected for animals at the surface and assumes that the model shaping parameter is fixed (θ =1). Solid line shows the median estimates and dashed lines show 95% Credibility Limit. Earlier surveys (1980–1986) (red squares) covered Clearwater Fiord and portions of the area outside of Clearwater Fiord. Consequently, they were considered to be negatively biased and were not used in fitting this model.

The 2015 abundance estimates for CSB are much lower than those used in the RPA (DFO 2005). In that exercise, a similar population model was fitted to two years of aerial survey data (1990 and 1999) with a harvest data series extending back to 1852. The 1999 survey abundance estimate was much higher than the 1990 survey, and is higher than any survey completed since (Figure 4). Consequently, the model used in the RPA estimated a 2002 stock size of 2,000 belugas (95% CI = 1,500–2,600 rounded to the nearest 100). The model projected that the stock could support harvests of up to 41 animals per year, with a 60% probability of reaching the recovery objective of 5,000 animals in 2095 (DFO 2005). Since then, there have been two additional aerial surveys of CSB and both have resulted in abundance estimates that are much lower than those produced by the 1999 survey. Fitting our model to the additional data reduced the estimate of 2002 abundance to 1,400 animals (CI = 1,000–2,200; rounded to the nearest 100). This value is 30% lower than the previous estimates of CS beluga abundance, but still within the 95% Credibility Interval of the RPA (DFO 2005).

Total Allowable Landed Catch

The current quota of 41 animals was based on model trajectories estimated from two aerial surveys flown in 1990 and 1999. Fitting the model to two additional surveys (2009 and 2014) has altered our understanding and indicates a declining stock (Figure 4). If the management objective is sustainable yield, then the probability of stock decline after 10 years is 0%, 48% and 95% for a TALC of 0, 3 and 5 animals, respectively.

Table 3 gives the probability of achieving the interim target level of allowing the CSB stock to increase to 1,235 animals within 10 years, under different harvest scenarios.

Table 3. Probability of success in reaching the interim target level of 1,235 animals within 10 years given different levels of harvest, reported as total allowable landed catch.

TALC level	Probability of success (%)
0	32
5	27
10	22
15	16
25	10

Depending on model runs, PBR estimates, which do not take into account other sources of human related mortality, were seven to eight animals (Table 2), assuming a recovery factor of 0.5, which DFO has used in the past for stocks considered as Threatened by COSEWIC. The Total Allowable Landed Catch would be five animals assuming that struck and lost, and other human sources of mortality represent 42% of the total catch.

Sources of Uncertainty

Model diagnostics indicated that the model had difficulty converging when using a much larger dataset that included catches extending back to 1920. This problem was solved when the model used a more restricted time-series of catch data (1960–2015), but cross correlation remained among model parameters such as: starting population size, current population size, struck and lost and environmental carrying capacity. This is due to the limited number of abundance estimates, as well as the considerable uncertainty in a number of parameters including the aerial survey estimates, the surface correction factors, the harvest time series, and the limited independent estimates of struck and lost. As a result, model estimates of abundance for the CSB stock are also uncertain. Surveys from other areas have shown that estimates produced from surveys of small beluga populations can be quite variable and uncertain. Several surveys were flown to determine CSB abundance prior to 1990, but these estimates were not used in the preferred model because they are thought to be negatively biased due to incomplete coverage in Clearwater Fiord (1980, 1982) and/or had limited coverage outside of Clearwater Fiord.

In many studies there is little consideration given to uncertainty in current and historic catch data. When modeled, this uncertainty is consequently incorporated into the estimates of struck and lost rates. Although designed to represent animals that are struck and have died (lost), but not recovered, the term also incorporates non-reporting. With respect to the CSB stock, there is considerable uncertainty associated with the harvest data. Over the last decade, there has been limited reporting of harvest levels. For these years (2004,2005, 2008 to 2010, 2012 to 2015), it was assumed that the entire quota of 41 animals had been taken. The direction and magnitude of the bias associated with this assumption is not known. Fitting the model, when harvest history information prior to 1960 was included, was also problematic suggesting that there are problems with historical catch numbers, or that application of a single struck and lost rate over the entire catch series is inappropriate.

CONCLUSIONS AND ADVICE

All model runs using different combinations of aerial survey data indicated that the stock currently numbers around 1,000 belugas. The preferred model fitted to four aerial surveys flown between 1990 and 2014 produced a 2015 estimate of 1,000 animals (rounded to the nearest 100) individuals (95% CI = 500 to 2,000).

Maintaining the current quota of 41 CSB will lead to further declines in the stock. If the stock is to recover to identified interim target levels, then harvest reductions are required. A longer time series of survey estimates, improved survey correction factors and improved harvest reporting (including struck and lost) are required to reduce uncertainty associated with the abundance estimates and trend.

SOURCES OF INFORMATION

This Science Advisory Report is from the April 6, April 20 and May 10, 2016 National Marine Mammal Peer-Review Meeting: Cumberland Sound Beluga. Additional publications from this meeting will be posted on the DFO Science Advisory Schedule as they become available.

COSEWIC. 2004. COSEWIC assessment and update status report on the beluga whale *Delphinapterus leucas* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. ix + 70 p.

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Marcoux, M., Young, B.G., Asselin, N.C., Watt, C A., Dunn, J.B., and Ferguson, S.H. 2016. Estimate of Cumberland Sound beluga (*Delphinapterus leucas*) population size from the 2014 visual and photographic aerial survey. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/037. iv + 19 p.

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